NARRATOR: Welcome to Intersections: The RIT Podcast. Are electronic cigarettes really a healthier alternative to tobacco products? Risa Robinson, head of RIT's department of mechanical engineering, talks with Edward Hensel, associate dean, about their unique research methods into how these devices are used and how they affect users' health.

RISA: So we're capturing the puffing behavior of a user every time they take a puff. So we have a monitoring device that attaches to their product, whether it be their electronic, their JUUL, their vape pen, their cigarette, it attaches to their product. And it measures every puff that they take. It measures the time that they take the puff. It measures the flow rate. It measures the duration. It measures the time in between puffs. And all of those types of behaviors are important in assessing the total amount of exposure they're getting, and also the time frequency at which they're getting the exposure. Are they vaping all day long? Or are they vaping once an hour for a discreet amount of time. All of these parameters go into how addicted a user is and how much exposure they get. By measuring their behavior with our monitor, we're able to assess the risk of one product relative to another. In the laboratory environment, we can capture the emissions but we can't capture the behavior.

EDWARD: I recall, Risa, when I first started working in the lab, one of the first things I asked you was, what sort of shortcomings you saw with monitors available on the marketplace? And what were the needs that drove the development of the RIT personal use monitor?

RISA: One, is that the monitoring devices that were available commercially were only able to capture the puffing patterns. But they weren't able to capture the inhalation patterns. And we needed to really capture both of those in able to enable us to get an estimate of exposure. Also at that time, electric cigarettes were starting to come on the market, and those monitoring devices weren't able to capture any puffing topography from the electronic cigarettes.

EDWARD: It seems like you're focusing a lot of the discussion now on the inhalation topography. That's kind of our future direction, whereas, up until now, a lot of the work has been done on the puffing topography. What's the difference between those?

RISA: The puffing topography is the behavior of the smoke as it is coming out of the cigarette or out of the e-cig. And the inhalation topography is how the person takes that smoke or that vapor into the respiratory tract. If you want to test two products side by side on a bench, they may look exactly the same in the laboratory if you puff those two products the same. But if you take those two products in to the natural environment and the person were to use those products, they may use them completely differently. They may puff them differently. They may inhale them differently. And it's that puffing behavior and that inhalation behavior that is what's going to affect their exposure to the harmful constituents. So, some of the preliminary data that we found were that users of low-nicotine e-liquids have a different behavior than users of high-nicotine e-liquids. Users of low-nicotine e-liquids compensate their behavior in order to get the amount of

nicotine in their blood that they need in order to maintain their addiction. That's something that you can't find in the laboratory environment. You can't measure that by machine puffing. You have to send our monitors out in the environment with the users in order to see that difference.

EDWARD: I think that distinction between machine puffing and natural environment puffing behavior is something that has come up time and time again in the lab. When I look back at the original machine puffing standards for cigarettes, which were pretty much based on a half sine wave, a very well-behaved, characterized puff. And then I looked at the raw data we were actually getting from field studies with human participants actually smoking cigarettes, those puffs that we saw in the real environment look nothing like the machine puffing standards. And then we see, regularly, that e-cig puffing looks quite a bit different than cigarette puffing behavior. So, I think that all ties back in with what you were describing.

RISA: And e-cig behavior from one person to another is very different. And e-cig behavior from one product, from one electronic cigarette is different than another electronic cigarette. We see different behavior for those who use a JUUL compared to those who use a vape pen compared to those who use box mods, for example.

EDWARD: Why do you think that is?

RISA: It's the difference in the design of the devices. Some devices are actually designed for a particular type of inhalation pattern. There are different inhalation patterns – direct-to-lung and mouth-to-lung. The mouth-to-lung inhalation pattern is typical of a cigarette type of behavior where you bring the puff into the mouth and then you inhale it into the lung. Some of these electronic cigarettes are being designed to be taken directly into the lung without a stopover in the mouth. And that's a very different exposure pattern, because if you're taking something into the mouth, you're limited to a fixed volume, a small volume. And then when you inhale it into the lung, you are diluting that, so you're not get as much exposure. Whereas, if you're taking it directly into the lung, you're getting a large cloud and all of that is going directly into the lung without any mixture of clean air. So, you're getting a very heavy exposure.

EDWARD: I think the thing that is substantially different about e-cigs is, because they are an electromechanical product, there are tons of design parameters that engineers can change to really design how these chemicals get delivered to the human. Whereas, in a combustible cigarette, ultimately they're burning tobacco.

RISA: Right.

EDWARD: Now they have all these different things they can dial in on.

RISA: Right. So, you bring up the cigarette. In the case of the cigarette, they designed something in called elasticity, so they actually designed the different ways that they packed the tobacco and the different makeup of the tobacco so that it may behave a

certain way in the lab under a certain puffing condition. But when you take it out and the person actually uses it, it behaves a completely different way. They had vent holes in the cigarettes. The vent holes aren't covered up in the lab, so you get one type of exposure. And when the user goes and smokes they're covering up the vent holes so that they're getting a nice, heavy dose of the smoke. In electronic cigarettes, like you said, there's hundreds of different things that the user can change on their own. They can change the power, they can change the air flow, they can change the nicotine concentration. So, you have to test these products under natural, daily activities in order to really figure out whether they're lower risk.

EDWARD: It kind of reminds me of the Volkswagen emissions testing scandal where they programmed the automobile to behave differently when it sensed that it was connected to an emissions testing machine. So, we're actually trying to measure products in the natural environment, not in a contrived laboratory setting. Because we send these monitors home with people for a week or more, we may be capturing thousands of puffs. Whereas, a lot of other laboratories will bring a study participant in to the lab for 30 minutes and capture a dozen or a couple of dozen puffs. So, we've had to automate all of the data processing and interpretation of thousands of puffs over dozens of users, and that's forced us to develop very robust algorithms for the signal processing and the data interpretation. As a result, I think we've removed a lot of the heuristics or the judgement call that other researchers may have to make in manually processing data. And I think one of the unique skill sets that we bring to the table is the monitoring capability. As all of these new products come into the marketplace, we can respond quickly and measure all these different products. The traditional monitors can't keep up. That's our challenge and our opportunity. There's a new product coming out every three months. We're trying to develop new monitors to keep up with those product innovations.

RISA: And because we have a very unique lab here. We have a multidisciplinary lab. We have an industrial designer. We have a computer engineer. Mechanical engineer.

EDWARD: Analytical chemist. Psychologist.

RISA: Industrial engineer. We pretty much have one of every discipline, which is what's needed to be very responsive to these electronic cigarettes as they come out on the market. We design a new monitoring device and then we can, very rapidly, test that in the field and inform regulatory policy in a timely manner. I don't think it's well accepted yet that switching folks from smoking to electronic cigarettes is a positive health benefit because we don't know, once they switch over to electronic cigarettes, will their nicotine addiction get worse? Or will they actually take in more nicotine than with the cigarette because they can vape all day long? So, we really don't know if there is a positive health benefit. Really, the crux of our work is trying to decide the relative risk between different electronic cigarette products and the relative risk between smoking and electronic cigarettes. And at a population level, do electronic cigarettes actually have a positive health impact? Because if you put electronic cigarettes on the market, and it does show that people who switch from smoking to electronic cigarettes, that's a

positive health impact. But if they're on the market, it's easier for young folks to get addicted then. At a population level, it may be a negative health benefit. So, how many are going to switch from smoking to electronic cigarettes compared to how many new addicted nicotine users are we going to get? And all of these in my mind are unanswered questions.

EDWARD: I think one of the challenges of this research is this is a large market both in the U.S. and around the world. There are billions and billions of dollars at stake every year. And there are hundreds of millions of dollars that are spent on company research to develop new products every year. So, we're trying to stay ahead of that new product introduction curve with a tiny fraction of the expense budget. If we look at the entire National Institutes of Health budget for tobacco research, it pales in comparison to the internal research and development budgets of the companies that are making these products.

RISA: I think that the problem itself is at the intersection of behavior and psychology and engineering. And so as we started looking into the problem and trying to solve the problem we realized we needed a behaviorist. We need to respond to these different e-cig products, so we need an industrial designer in order to help us design the casing. Now we have the JUUL come out. And that's much smaller, so now we need to reduce the size and we need a computer engineer in order to develop the new core boards that are a smaller size. Over time it has evolved, but it is a multidisciplinary problem by nature.

EDWARD: One of our key strategies has been to identify faculty and students who are interested and eager and passionate about working on a particular topic – and then how do we leverage that passion in a way that contributes to the overall goals? We may not know exactly how we're going to use a new skill set when it joins the team, but it's a high-quality individual with a lot of passion to do something eager. And that opens up new opportunities that we maybe hadn't even thought of before.

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